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2 Imaging and characterizing fresh and metamorphosed snow crystals with low temperature scanning electron microscopy

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Abstract

A technique, known as low temperature scanning electron microscopy (SEM), has been used to image precipitating and metamorphosed snow crystals, as well as glacial ice. This review summarizes the methods that are used to collect, transport and store samples of snow and ice and illustrates the basic types of snow crystals that occur in nature along with the changes that they undergo in the snowpack. In addition, the study illustrates firn and glacial ice, which were also sampled and examined with the low temperature SEM. The results illustrate the ease and

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the resolution with which samples of snow and ice can be observed, studied and photographed. Until recently, studies of snow and ice were largely restricted to a hand lens or the light microscope (LM); the laboratory and the instrumentation had to be cooled to temperatures below freezing, frequently near a collection site. This requirement, which is expensive and inconvenient, is not necessary for observations with the low temperature SEM. Alternatively, samples are easily collected in the field and have been shipped to the electron microscopy laboratory by common air carrier from distances as far as 8,000 km. Delicate specimens of snow crystals and ice grains survive the shipment procedures and have been stored as long as three years without undergoing any structural changes that can be detected by LM or SEM. During observation with the SEM, the samples are not subjected to melting or sublimation artifacts and can be observed for hours with no detectable structural changes. Furthermore, the tilting stage of the SEM permits the recording of photographs that contain the information necessary for three-dimensional imaging. As a result, visualization of the true shapes of snowflakes, snow crystals, snow clusters, ice grains and their interspersed air spaces is easily achieved.

1. Introduction

Through the ages, the shapes of snowflakes have intrigued man for a variety of reasons. His inquisitive nature was probably responsible for the recorded descriptions of snow, which were based on visual observations that began about 2000 years ago. Curiosity may also have been responsible for the fact that snow was among first objects observed with the newly discovered light microscope in the 17th century. Alternatively, the beauty of nature was apparently responsible for motivating Wilson Bentley, who successfully interfaced the camera with the microscope at the turn of the 20th century and photographed numerous images of snow crystals. Scientific motivation undoubtedly inspired Nakaya to determine systematically how temperatures and humidity influenced the growth and shapes of snow crystals. Today, investigators in diverse scientific fields are investigating the shape of snow crystals to help solve or abate economic problems and social disasters. For example, scientific models, which take into consideration the shapes and sizes of snow crystals, are being written to estimate the water equivalent present in the winter snowpack. These estimates provide information needed for agricultural use, flood control and dam management. Similarly, determining the shape and metamorphosis of snow crystals can be used to solve problems relating to drag coefficients on runways, aircraft icing, and avalanche predictions. This manuscript briefly reviews mans early attempts to elucidate the structure of snow and details the current investigations that are being pursued with a relatively new instrument, namely the low temperature SEM, that can magnify and image snow crystals and ice grains far beyond any technique previously available to man.

6. Discussion

A. Importance of snow structure to agriculture

Snow may cover up to 53% of the land surface in the Northern Hemisphere (28) and up to 44% of the land areas of the world at any one time. This snow cover supplies nearly one third of the water that is used for the irrigation and the growth of crops (30). For this reason, estimates of the quantity of water that is present in the winter snowpack are important to agriculture because they are related to the amount of moisture that will be available for the pending growing season. To achieve snow water equivalent estimates, scientists have used microwave remote sensing techniques on snowpacks prior to melting (31, 52). Unfortunately, the estimates appear to be confounded by the shapes and sizes of the crystals in the snowpack. Therefore, increasing our knowledge of these factors may help to increase the accuracy of the models that are used for estimating snow water equivalents.